Disease Law and Forecasting of the Needle Blight of *Pinus sylvestris* var. *mongolica*

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ABSTRACT Fixed quadrates were established in different stands. In continued six years, the occurring period, occurring amounts and the relation between epidemic disease and environmental factors were investigated according to spraying laws of spores and accounting measures of disease ranking. The occuring peak period of the disease was from the last ten days of May to the second ten days of June. The epidemic period was from the last ten days of June to the second ten days of July and the initial decease period was from the last ten days of July to the beginning of September. The change of the disease depended on air temperature, relative humidity and precipitation. A multiple linear regression model was established using computer, which can predict the disease index(Y) of 10 days later, with more than 95% reliability

Key words: *Pinus sylvestris* var *mongolica*, Disease, Needle blight, Septoria pini-putnilae Sawada, Dothistroma pini Hulbary, Forecast technique, Pathogen

Introduction

Needle blight of *Pinus sylvestris* var *mongolica* is one of the main disease on *Pinus sylvestris* var. *mongolica* which is a native species in the area between Hulunbeir grassland and forest. This disease is noted for serious infestation, fast spread and difficult to be controlled. In the past, the control work was not conducted untill the disease symptom came on obviously. By the time the disease symptom came on , the disease was difficult to be controlled. Forecasting the occurring period and occurring amounts of needle blight accurately is a key to determine control time and how to control. The forecasting of occurring period, occurring amounts and control index can improve the management level of the needle blight disease. The forecasting technique of the needle blight of *Pinus sylvestris* var. *mongolica* was rarely reported at home and abroad. From 1994, using spore trapping, we investigated the occurring period, occurring amounts and their relations with environmental factors. Using regressing method and computer, we established a multiple linear regression model.

Materials and Methods

Spore trapping and disease investigating

Observation spots and fixed sample plots were set up in Honghuarji, Huihe and Toudaoqiao forest farms. Survey was carried out once every 20 ~30 days. In Qingshougling, Wuqinian and Ximiaopu, the survey was made once every 10 days by a five-ranks standard(Table 1). Thirty sample trees were chosen in every sample plot. The disease index was calculated using Formula 1. Average disease index was calculated.

Table 1. The standard table of disease index ranking

Disease ranking	Value	The condition of disease
I	0	no disease leaves
II	1	less than 25% disease leaves
III	2	26%-50% disease leaves
IV	3	51%-75% disease leaves
V	4	more than 76% disease leaves

$$T = \frac{\sum(c \times d)}{n \times e} \times 100 \qquad (1)$$

where:

T is disease index

c is number of diseased trees

d is representative value;

e is the value of the most serious rank;

n is the sum of trees in every rank.

Factors

The occurring time, occurring amounts and environmental factors were investigated every 10 days since 1991 to find the relationship among them . The following climatic factors are worked as selected factors.

(1) Average air temperature of ten days X_1;

(2) Average relative humidity of ten days X_2;

(3) Total precipitation of ten days X_3;

(4) Initial disease index X_4;

(5) Precipitation frequency X_5 (rainfall days/total days);

(6)Precipitation intensity X_6 (rainfall amounts/ rainfall days);

(7) Climate index of ten days X_7 (average relative humidity / average temperature);

(8) Temperature rainfall index of ten days X_8 (total rainfall/ average temperature).

The data of 8 factors from 1990 to June of 1995 were from local hydrographic station and meteorological station . The data from July of 1995 to Aug. of 1996 were from observation made by our research group.

Results Analysis

Spores trapping

The epidemic laws was found through spores trapping. The peak period of the disease was from the last ten days of May to the second ten days of June. The epidemic period was from the last 10 days of June to the second 10 days of July. The initial disease period was from the last 10 days of July to the beginning of September. The disease stopped infection in October.

Forecasting laws

Incubation period of the disease was 13-15 days and 35-40 days respectively. Correlation check of eight factors was carried out. The factors are listed as follows.(Y represents the highest disease index).

Table 2. The standard table of disease index ranking

Observing time	Factors								
	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	Y
5/1/1991-5/10/1991	12.94	40.20	17.30	27.0	0.4	4.3250	0.322	1.3369	27.2
5/11/1991-5/20/1991	19.33	36.10	0.000	27.2	0.0	0.0000	0.535	0.0000	29.5
5/21/1991-5/31/1991	18.51	33.80	4.000	29.5	0.2	2.4000	0.537	0.2204	30.0
6/1/1991-6/10/1991	19.38	42.90	22.80	30.0	0.6	3.8000	0.452	1.1765	32.4
6/11/1991-6/20/1991	19.15	51.90	12.30	32.4	0.3	4.1000	0.369	0.6423	33.0
6/21/1991-6/30/1991	21.05	54.70	30.40	33.0	0.3	10.133	0.385	1.4442	35.6
7/1/1991-7/10/1991	19.3	69.90	49.90	35.6	0.6	8.3167	0.276	2.5855	47.8
7/11/1991-7/20/1991	21.07	75.40	70.70	47.8	0.5	14.080	0.279	3.3412	49.6
7/21/1991-7/31/1991	23.42	73.00	29.00	49.6	0.5	5.8000	0.321	1.2383	50.0
8/1/1991-8/10/1991	28.14	50.60	29.40	50.0	0.2	14.725	0.556	1.1466	56.9
8/11/1991-8/20/1991	22.33	67.00	39.00	56.9	0.6	6.5000	0.333	1.7465	57.6
8/21/1991-8/31/1991	25.52	66.70	28.90	57.6	0.5	5.7800	0.383	1.1324	61.7
9/1/1991-9/10/1991	13.06	73.60	71.00	61.7	0.6	11.833	0.177	5.4364	50.0
9/11/1991-9/20/1991	15.55	52.80	13.40	50.0	0.3	4.4667	0.295	0.8617	52.4
9/21/1991-9/30/1991	14.47	46.30	4.900	52.4	0.3	1.6333	0.313	0.3386	49.7
5/1/1992-5/10/1992	12.05	42.50	30.50	24.8	0.5	6.1000	0.284	2.5311	31.1
5/11/1992-5/20/1992	18.01	35.50	5.200	31.1	0.3	1.7333	0.507	0.2887	34.6
5/21/1992-5/31/1992	27.43	37.30	0.000	34.6	0.0	0.0000	0.735	0.0000	35.1
6/1/1992-6/10/1992	14.19	55.30	14.50	35.1	0.5	2.9000	0.257	1.0288	36.9
6/11/1992-6/20/1992	21.58	53.20	28.40	36.9	0.4	7.1000	0.406	1.3160	38.0
6/21/1992-6/30/1992	21.05	64.60	33.00	38.0	0.6	5.5000	0.326	1.56777	39.7
7/1/1992-7/10/1992	24.20	48.10	0.100	39.7	0.1	0.1000	0.503	0.0041	39.9
7/11/1991-7/20/1991	24.11	49.30	27.30	39.9	0.3	0.1000	0.489.	1.1323	40.2
7/21/1992-7/31/1992	25.74	66.90	61.00	40.2	0.5	12.200	0.385	2.3699	41.3
8/1/1992-8/10/1992	20.76	65.30	40.30	41.3	0.4	10.075	0.318	1.9412	44.5
8/11/1992-8/20/1992	20.29	61.80	3.300	44.5	0.5	0.6600	0.328	0.1626	49.6

Continue Table 2

8/21/1992-8/31/1992	22.19	70.70	63.70	49.6	0.6	10.617	0.314	2.8707	50.7
9/1/1992-9/10/1992	14.31	70.80	32.10	50.7	0.6	5.3500	0.202	2.2432	44.7
9/11/1992-9/20/1992	12.34	60.80	31.40	44.7	0.5	6.2800	0.203	2.5446	38.2
9/21/1992-9/30/1992	10.50	63.70	2.200	38.2	0.2	1.1000	0.165	0.2095	32.5
5/1/1993-5/10/1993	12.29	39.60	9.800	27.3	0.3	32.667	0.310	0.7974	29.6
5/11/1993-5/20/1993	17.45	28.10	10.00	29.6	0.2	5.0000	0.621	0.5731	30.4
5/21/1993-5/31/1993	19.46	30.40	1.700	30.4	0.2	0.8500	0.640	0.0874	34.7
6/1/1993-6/10/1993	19.19	52.30	22.20	34.7	0.5	4.4400	0.367	1.1569	37.3
6/11/1993-6/20/1993	19.25	63.70	45.00	37.3	0.7	6.4296	0.302	2.3377	39.4
6/21/1993-6/30/1993	21.20	50.30	82.40	39.4	0.7	3.2000	0.421	1.0566	41.1
7/1/1993-7/10/1993	20.20	50.30	48.60	41.1	0.8	6.0750	0.402	2.4009	42.5
7/11/1993-7/20/1993	21.28	76.30	60.30	42.5	0.7	8.6143	0.249	2.8336	46.7
7/21/1993-7/31/1993	23.86	79.90	15.00	46.7	0.5	3.0000	0.299	0.6287	48.1
8/1/1993-8/10/1993	22.38	91.30	16.70	48.1	0.5	3.3400	0.245	0.7462	51.8
8/11/1993-8/20/1993	19.93	57.30	40.40	51.8	0.5	8.0800	0.348	2.0271	56.7
8/21/1993-8/31/1993	20.70	71.10	36.50	56.7	0.5	7.3000	0.291	1.7633	64.0
9/1/1993-9/10/1993	23.92	42.80	0.000	64.0	0.0	0.0000	0.559	0.0000	54.7
9/11/1993-9/20/1993	14.99	49.10	13.20	54.7	0.4	3.3000	0.305	0.8806	48.6
9/21/1993-9/30/1993	12.65	64.90	24.50	48.6	0.4	6.1250	0.195	1.9368	37.9
5/1/1994-5/10/1994	14.66	22.01	2.000	25.8	0.2	1.0000	0.666	0.1364	27.8
5/11/1994-5/20/1994	16.28	19.54	3.570	27.8	0.2	1.7850	0.833	0.2193	28.2
5/21/1994-5/31/1994	20.34	34.52.	4.25	28.2	0.3	1.4167	0.589	0.2089	29.4
6/1/1994-6/10/1994	23.50	33.00	32.70	29.4	0.4	8.1875	0.712	1.3936	29.7
6/11/1994-6/20/1994	26.12	36.09	20.25	29.7	0.3	6.7500	0.724	0.7753	32.6
6/21/1994-6/30/1994	22.77	63.20	29.00	32.6	0.6	4.8333	0.360	1.2736	37.4
7/1/1994-7/10/1994	22.30	62.26	21.50	37.4	0.6	3.5833	0.358	0.9641	37.8
7/11/1994-7/20/1994	27.63	52.41	27.75	37.8	0.3	9.2500	0.527	1.0043	39.5
5/1/1995-5/10/1995	10.42	28.05	0.000	21.4	0.0	0.0000	0.371	0.0000	25.7
5/11/1995-5/20/1995	17.44	15.71	0.000	25.7	0.0	0.0000	1.110	0.0000	26.0
5/21/1995-5/31/1995	14.98	40.96	0.000	26.0	0.0	0.0000	0.367	0.0000	27.9
6/1/1995-6/10/1995	21.26	42.97	4.750	27.9	0.2	2.3750	0.495	0.2234	30.2
6/11/1995-6/20/1995	23.50	52.80	4.500	30.2	0.4	1.1250	0.445	0.1915	31.4
6/21/1995-6/30/1995	19.51	62.37	5.750	31.4	0.3	1.9167	0.313	0.2947	36.5
7/1/1995-7/10/1995	22.85	58.71	38.50	36.5	0.3	1.2833	0.389	1.6850	38.0
7/11/1995-7/20/1995	25.29	50.07	0.000	38.0	0.0	0.0000	0.505	0.0000	40.1
7/21/1995-7/31/1995	27.93	52.21	15.00	40.1	0.1	15.000	0.535	0.5370	42.5
8/1/1995-8/10/1995	24.71	52.29	23.75	42.5	0.3	7.9167	0.473	0.9611	44.6
8/11/1995-8/20/1995	21.94	46.06	6.500	44.6	0.2	3.2500	0.473	0.2963	47.3
8/21/1995-8/31/1995	28.62	45.35	10.00	47.3	0.1	10.000	0.631	0.3494	43.5
9/1/1995-9/10/1995	16.83	44.20	2.750	43.5	0.4	0.6875	0.381	0.1634	36.0
9/11/1995-9/20/1995	20.45	27.22	0.250	36.0	0.1	0.2500	0.751	0.0122	31.4
9/21/1995-9/30/1995	13.47	49.73	23.50	31.4	0.3	7.8333	0.271	1.7446	28.6

Based on the data from Table 2, the multiple regression model for forecasting the needle blight of *Pinus sylvestris* var *mongolica* is established as:

$$Y=4.0227X_1+0.8947X_2+1.3677X_3+1.0173X_4-10.6707X_5+31.7728X_6-3.3589X_7-54.8996X_8-11.8456 \quad (r=0.92)$$

Where:

X_1--Average air temperature of ten days;

X_2-Average relative humidity of ten days;

X_3--Total precipitation of ten days;

X_4--Initial disease index;

X_5--Precipitation frequency (rainfall days/total days);

X_6--Precipitation intensity(X_3/rainfall days);

X_7--Climate index in ten days($X_7=X_2/X_1$)

X_8--Temperature rainfall index in ten days ($X_8=X_3/X_1$);

Y--Disease index 10 days late.

The partial related factor of Y and X_4 is 0.841782729. It reaches obvious level, compared with other factors.

Checks of forecasted model on other data

Using other 6 set of data, we forecasted the disease index, and compare the forecasted data with observed data(Table 2). The error is less then ±3. The results of check: X_2=0.388, if α=0.05, f=5 then X_2=1.145. The model is reliable.

Table 3. The check of the model

Initial time to observing time(dd mm)	Observed value (a)	Forecasted value(c)	Error (a-c)
6/3/1996-6/14/1996	34.9	32.4	+2.5
6/14/1996-6/24/1996	45.6	45.2	+0.5
7/1/1996-7/11/1996	60.8	59.2	+1.6
7/4/1996-7/15/1996	51.4	49.0	+2.4
8/2/1996-8/13/1996	63.5	63.5	+0
5/7/1996-5/18/1996	35.4	36.7	-1.3

Results

The disease peak period was from the last ten days of May to the second ten days of June. Epidemic period was from the last ten days of June to the second ten days of July. Initial disease period was from the last ten days of july to the beginning of September. The disease stopped in October.

According to the epidemic law, within the forecasting time, X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8 were used to established a forecasting model:

$$Y=4.0227X_1+0.8947X_2+1.3677X_3+1.0173X_4+10.6707X_5+31.7728X_6-3.3589X_7-54.8996X_8-11.8465$$

The model can forecast the disease index (Y) of 10 days late. The model is reliable.

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(**Responsible Editor**: Chai Ruihai)